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ABSTRACT

This instructional unit is one of 10 developed by students on various energy-related areas that deals specifically with fossil fuels. Some topics covered are historic facts, development of fuels, history of oil production, current and future trends of the oil industry, refining fossil fuels, and environmental problems. Material in each unit may include some or all of the following: terminal and specific objectives, list of references, information sheet with terms and definitions, informative materials, transparency masters, assignment sheet(s), and unit test with answers. (YLB)

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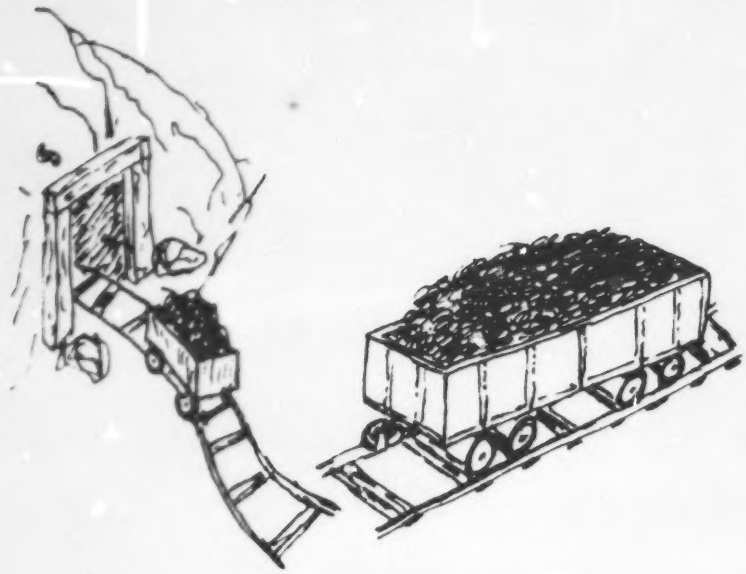
# FOSSIL FUELS



by

Ron Crank

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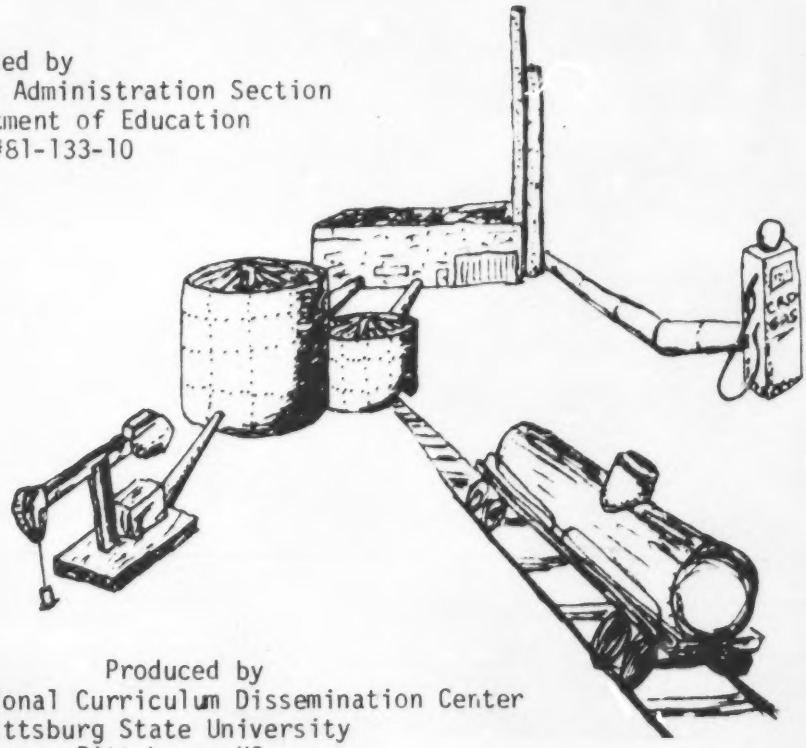

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# FOSSIL FUELS

## INFORMATION SHEET

I. Terms and definitions

A. Hydrocarbons - Large class of organic compounds containing only carbon and hydrogen.

B. Kerosene - Flammable hydrocarbon oil used for burning in lamps, heaters, and furnaces; fuel also used for jet engines and as solvent or thinner.

C. Methane - Colorless odorless flammable gas. Occurs naturally as a product of decomposition of organic matter.

D. Refining - Action or process of removing impurities from crude or impure material -- petroleum; fractional distillation usually followed by other processing (or cracking).

E. Seismic - Shock or earth vibrations produced by earthquake or artificially by geophysical prospecting.

F. Sour-crude - High sulfur crude oil.

G. Sweet-crude - Low sulfur crude oil.

H. Sweetening process - Process of removing sulfur from crude oil.

I. "Wild-catting" - To drill or prospect an experimental oil or gas well in territory not known to be productive.

II. References

A. Steinhart, Carol and John. Energy Sources, Use, and Role in Human Affairs. Massachusetts: Duxbury Press, 1974.

B. Shultis, J. Kenneth (edited by). Perspectives in Energy: 1977. Manhattan, KS: Kansas State University, 1977.

C. Fowler, John M. Energy and the Environment. New York: McGraw-Hill Book Company, 1975.

FOSSIL FUELS

Many statements about fossil fuels are correct; many are not. Major areas to be discussed are: the historic facts, the development, current topics and future expectations. Why has there been a continual increase in the use of petroleum? How has petroleum been used? Are these uses necessary or may something else serve as well? These are just a few questions to be answered in this unit.

Historically

Man first discovered fossil fuels after he had been on earth two million years. He discovered "rocks that burn" or shale oil. He also discovered petroleum. Within 1500 years man will have burned all the fossil fuels that can be taken from the earth. This period of burning fossil fuels will be brief compared to the history of man. (See TM.)

The fossil fuel family includes crude oil, natural gas, tar sands, coal, lignite and oil shale. This is also the petroleum family of hydrocarbons.

The oldest known petroleum was formed half a billion years ago. The most commercial valuable deposits are less than half as old. That is, they are less than 250 million years old. This formation is constantly going on. Early stages of formation can still be observed in the Black Sea and Gulf of Mexico.

Half a billion years ago, petroleum was just beginning to form. Life in the oceans consisted of all the major groups of animals. (The vertebrates was an exception). Marine life was plentiful in shallow seas and coastal waters. Anaerobic microorganisms lived in the stagnant areas of the sea. These microorganisms could survive there because they do not use oxygen to live. The microorganisms were on earth before there was any plant life. When plant life began, oxygen was

dispersed to the air and water. Many plants and animals could not live in water that was part oxygen. So they died and settled into the bottom mud. These corpses were then decomposed. A residue of hydrocarbon molecules were left behind. This process continued, adding more layers of decomposed corpses. This accumulation of sediments increased the pressure and temperature in the bottom layers.

In time, the molecular structure was rearranged into straight-chain molecules, branched-chain molecules and ring-shaped molecules. This rearrangement was due to heat and pressure. This was aided by the action of microbes.

It takes many years to convert organic sediments into oil. The first stages we can observe take 3000-9000 years.

These organic sediments contain a large amount of sea water. Sediments are continually buried under layers of mud and organic matter. Droplets of petroleum go into the sea water. The liquid goes out and up as the earth moves and pressure is increased. Thus, rocks are made firm. Eventually, the petroleum separates from the water. It rises higher than water because of its lower density. It sinks lower than water because it will not allow water or oxygen to enter. Petroleum can leave rocks in which it was formed. It moves through the porous surface of the rock. It becomes trapped by non-porous rock. It then collects in "oil pools." The porous rock is filled with the denser petroleum instead of ground water.

Different forms of petroleum range from tarry compounds to methane gas. Tarry and wax compound have a molecular weight of 300 or more and a boiling point above 500° C. On the other end of the scale is methane. Methane has a molecular weight of 16. These petroleum molecules vary in

amounts of oxygen, nitrogen and sulfur. Normally methane mixes with liquid petroleum. When there is an excess of gas, it bubbles to the top. It then forms a gas cap over the oil pool. (See TM 2.)

The gas, oil and ground water are under high pressure. When this pressure gets too great for the surrounding material it "blows out". Pressure is one cause of oil well gushers or blowouts. When this pressure is properly controlled, it can aid in the removal of oil or gas. Whenever cracks in the surrounding material occur, oil or gas escapes.

Natural cracks or seeps have been known to be used for thousand of years. 5,000 years ago Sumerian's drove chariots over roads paved with asphalt. The Greeks used natural petroleum for weapons. Blazing jets of escaping natural gas was worshipped by ancient fire worshippers along the Caspian Sea. There is a theory that King Nebuchadnezzar's fiery furnace was burning seepage of natural gas. The "Eternal Fires" of Mesopotamia were a curiosity during Biblical times. The Egyptians used materials from natural petroleum seeps for the preparation of mummies Asphalt was used to caulk boats in the Middle East and along the Pacific coast of America. The Burmese have collected oil of surface seeps and shallow hand-dug wells for centuries.

Story of Oil Production

The first oil fields were discovered by chance or by digging in the area of a natural seep. The oil industry as we know it today began in 1848. Drillers searching for water struck oil. Colonel Edwin Drake then drilled for oil purposely. This drilling by chance was called "Wiid-catting". This "Wild-Cat" period was mostly unproductive.

The discovery of oil and gas fields have become increasingly complicated. In 1855, geologists were pointing out that oil pools tended to occur in certain types of geological structures.

Science has played an important part in the discovering of oil fields. Currently, fields are discovered by seismic exploration, electric analysis, gravitational methods and by magnetic methods. Explorations have long taken place around populated areas. Explorations are now taking place at the bottom of the sea. Desert areas and subpolar regions are also being explored.

The first oil well was 21 meters (69 feet) deep. Modern wells go down as far as 8 kilometers (5 miles). The basic techniques of drilling have not changed much over the years.

The quest for oil began when whale oil and other common lighting materials became scarce. The first demand on the petroleum family was kerosene. There was a small market for lubricating oils. Oils were also used as medicine.

In the beginning, oil production was much greater than the need. This resulted in low prices and much waste. The oil production industry tried to find new uses for their product. At the beginning, oil could hardly be given away. The future looked bad when electric lighting was invented. The future brightened when it was discovered that oil could fire a boiler as well as coal. The oil industry was really booming when the automobile came into use. By 1910, fuel oil was the number one refinery product. At the end of World War I, fuel oil had taken over many of the coal markets. Oil had entered manufacturing, shipping and the railroads. There was a rapid growth for oil in domestic use and in generating electricity. Americans needed more oil as the popularity of the internal combustion engines grew. The demand for crude oil is ever increasing at a terrific rate. This rate cannot continue forever. Chronic

shortages are being predicted for this increased use rate.

Current and Future Trends of the Oil Industry

The rate of exploration is related to the rate of production. Amounts of crude oil left in existence are proved by exploration. This amount differs from the amount which can be recovered by current methods. This amount to be recovered also has to be economical to recover. The ceiling is the total amounts of oil that can be recovered that exists.

The continental U.S. may have already reached its peak in oil production. Alaskan fields may serve to delay the peak for the entire country. The likely effect will be to delay the decline rate of production. World peak production is expected near the turn of the century. Industry is currently geared to an annual increase in production. This rate is about 5 percent.

The production of this exhaustable resource is shown by a normal growth curve. (See TM.) Each point of growth is determined by two factors. One factor is the current rate of growth. The other is the ultimate size that will be reached. Production always lags behind discovery. As discovery and production reach the same maximum level, the reserves fall to zero. (See TM.) See TM to understand what happens to the reserves as discovery and production increase and then decrease to zero. The TM is the curve of actual discovery and production rates to 1980. The typical growth rate of crude oil in the U.S. is 5.86 percent per year. This does not include Alaska. Compare the growth curve with the estimates of the total oil available. This shows that 80 percent of America's oil production will be a 65 year period between 1936 and 1999.

There are several unknowns in the industrial development of fossil fuels. The absolute amount of oil is not known. Future economic and political conditions cannot be predicted. There may be a breakthrough in energy technology.

Past techniques have left up to three-quarters of oil in the ground. Current techniques have increased production up to 40 percent. These techniques include fluid injection, solvent injection and fracturing technique. There have been advances in theory and technology in oil exploration. However, discoveries per foot of drilling has fallen. Thirty-five years ago it was 250 barrels per foot. The discoveries now are only 35 barrels per foot. Crude oil supplies are running out. New supplies are hard to find.

Refining Fossil Fuels

The purpose of refining crude oil is to create those products which the public demands. Petroleum is generally not used directly. Crude oils are classified into three categories. They are parafin-based, intermediate-based and napthene based. The quantity of sulfur in the crude influences the design and operation of the refinery. High sulfur crude oils are called sour crudes. Low sulfur crude oils are called sweet crudes. When the sulfur is high, then it needs to be removed. The process of removing sulfur is the sweetening process. Specific gravity also influences the refinery process.

There are many important products produced at a refinery. Natural and refinery gas are used for household and industrial fuel. Gasoline is used for fuel for internal-combustion engines. Naptha and benzene are put in cleaners solvents, paint thinners, chemical solvents and stocks for the blending of motor fuels. Jet fuel is a fuel for jet or

gas turbine engines and rockets. Kerosene was used as a burning oil for household lamps.

Distillates, diesel fuel and gas oil (distilled products) are fuels for industrial and household furnaces. They are used as enriching agents in gas manufacture. They are also fuels for diesel engines. They are used as absorbents for hydrocarbon gases.

Neutral oils are light lubricating oils stocks for the making of motor oils and light machine oils. Bright stock is used as heavy lubricating -- oil stocks used as lubricants. These lubricants are used in steam-engine cylinders or for the manufacture of bright stock. Cylinder oils are usually filtered but not dewaxed. Fuel oil is a residual product used as an industrial fuel. Petroleum coke is a solid industrial fuel.

Tar and asphalt are used in roofing materials, asphalt, road oil and protective coating. Petrolatum (microcrystalline wax) is the base material in making greases, salves, ointments and package sealing. Paraffin wax is used in the manufacture of wax paper, insulating material and package sealing. Paraffin wax has many more uses, but these are a few.

Fuel Shortages

Until World War II, the U.S. was a net exporter of energy, including petroleum. Since 1947, the U.S. has increasingly depended on foreign oil. In mid-1970, the U.S. imported 30 percent of its petroleum. If the government and oil industry does not keep the country self-sufficient and restrict imports, the U.S. could be importing 60% by 1985. There is a need for managing the production and use of fuels.

There are all kinds of problems in developing a national energy policy. These problems also indicate a need for an energy policy. These problems range from political problems to technology problems. They range from economic problems to environmental problems.

Estimates indicate that there is only enough fuel for "half a dozen human generations or so." Exploration is becoming more difficult. Exploration is less rewarding. The demand for clean fuel is growing. Costs will increase as fuel needs are met from poor and more deeply buried deposits. More energy will be used in fuel production than can be gained by burning it. Currently 7 percent of the annual energy produced is used in the extraction and refining of petroleum.

Environmental Problems

Environmental problems are found at every stage of production of fossil fuels. These occur in exploration, in production and processing, in transportation and storage, and last, in the use and disposal of fossil fuels.

Exploration of the subpolar regions receive the most abuse. It disturbs the balance between permafrost and ground cover. There is rapid erosion which takes centuries to repair. The need for people and machines for exploring for fossil fuels places a severe strain on the Arctic environment. In most other places in the world, the environment is not so affected. The damage done is uaually slight and takes a short time to recover.

The environment starts to really break down with the production and processing stages for fossil fuels. It pollutes streams and ground water. Mining scars the landscape. It is then costly to

reclaim the mined areas. When the earth is reclaimed, it is usually years before the process is begun. During all this time, the soil is eroding. Sediment clogs stream channels. Fish habitats are destroyed. Nearby land is frequently flooded and crops destroyed. In the mining and drilling production both workers are subjected to sickness, injury and death.

Drilling offshore for petroleum can cause leakages. This leakage disrupts the natural balance of life. The oil forms a slick which cuts off the area's oxygen supply. This causes marine life to suffocate. Birds of the sea which get trapped by an oil slick get oil on their feathers. They cannot get it off and cannot fly because of the added weight.

Pollution from refineries are evident by sight and smell. Each year refineries put 12 billion or more kilograms of carbon monoxide into the air. They put about 3.5 billion kilograms of sulfur oxides into the air. They release 10 billion plus kilograms of gaseous hydrocarbons. Every year the refineries let one billion kilograms of particulate matter into the air. Other by-products of the refinery are ammonia, phenols, napthalene, cresol and sulfides. All of the later do not produce a pleasant smell.

Transportation and storage present some new technological problems. They add to problems made by the production of fossil fuels.

Tanker spills, which are akin to ocean drill leaks, have received lots of publicity by the media. Oil pollution at sea kills organisms by suffocation. Products of petroleum (such as phenol) may be toxic to plant and animal life. Long range effects of this pollution could lead to the extinction of many marine species.

Another mode of transportation is by way of pipeline. The pipeline, also, could develop leaks and pollute underground and ground water. It would also cause the plant life to die in the immediate area of the leak. The Alaska pipeline could cause an imbalance of fault zones and areas of seismic activity. There had been some concern about the effects on migratory herds. Actually, these herds were mostly effected during building of the pipeline. The herds now use the pipeline for shelter.

The use and disposal of fossil fuels add a whole new set of problems. Eighty percent of all air pollution is produced by burning fossil fuels (See TM.) The major problem with coal is the sulfur pollution. There are four major elements of fossil fuels that create pollution problems. (See TM's.) These elements are nitrogen, carbon, hydrogen and sulfur. Sulfur oxides injure both physical structures and living things. Power plants using residual fuel oil produce about the same levels of sulfur, nitrogen oxides and carbon monoxide as coal-fired plants.

Most carbon monoxide is produced by inefficient internal combustion engines. There are three effects of carbon monoxide. Carbon monoxide competes with oxygen on the red blood cells. It accumulates in the blood during prolonged exposure. As a result, the person becomes less alert.

Hydrocarbons in the atmosphere undergo a chemical reaction. This results in smog. Hydrocarbons in the atmosphere are returned to earth by rain. Some go into the ground where they are acted upon by soil bacteria. Others enter the waterways. They join others to add to the hydrocarbon burden of the hydrosphere. All represent energy lost to man. Some hydrocarbons are carcinogens. They can cause cancer.

The American people are realizing the environmental problems of fossil fuel production. They also understand that there is a limit to the amount of fossil fuels available. It will take time for the people to change their ways. It will take time for them to discover new technologies. There is research being conducted on what may be substituted for fossil fuels.

FOSSIL FUELS

ASSIGNMENT SHEET #1

1. React to the following statement in terms of the current fossil fuels situation.

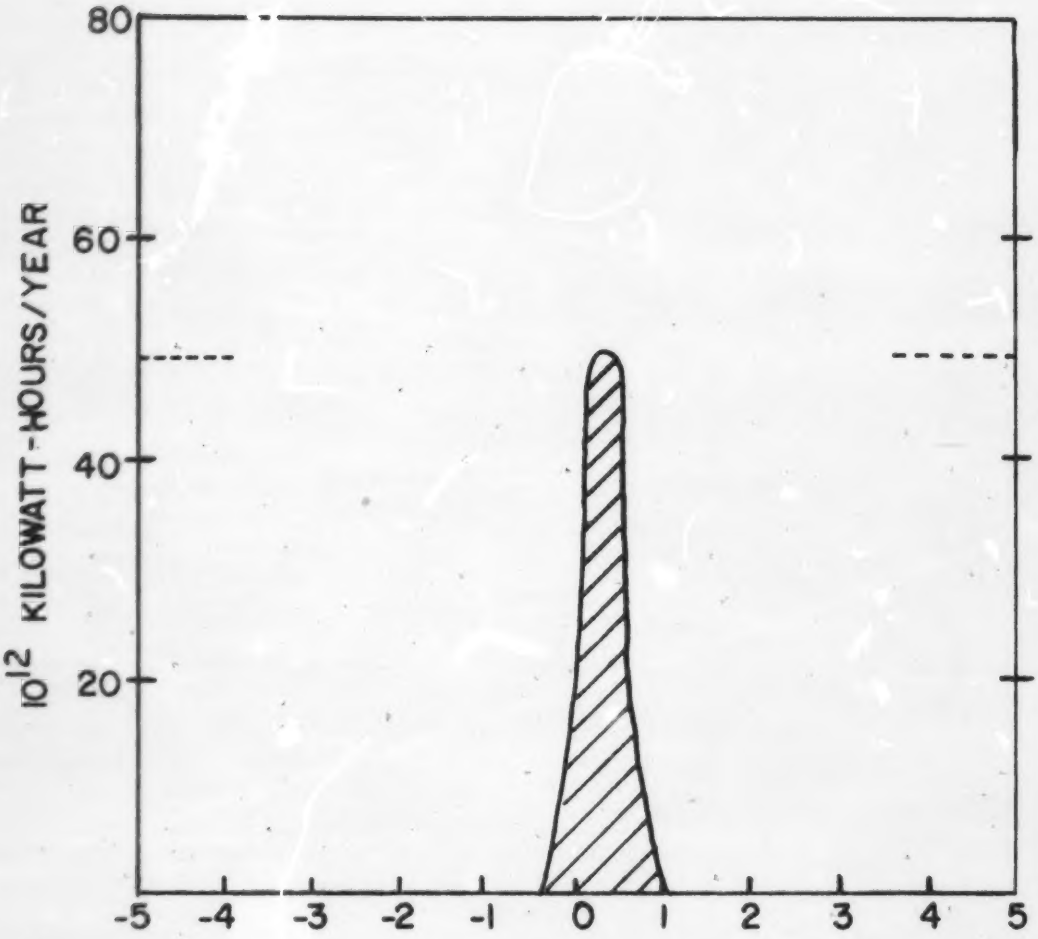
   "The amount of an exhaustable resource that is ultimately produced cannot exceed the amount initially present, and every drop that is withdrawn decreases the amount that remains."

2. What does this mean in terms of future industrial development of fossil fuel industries?

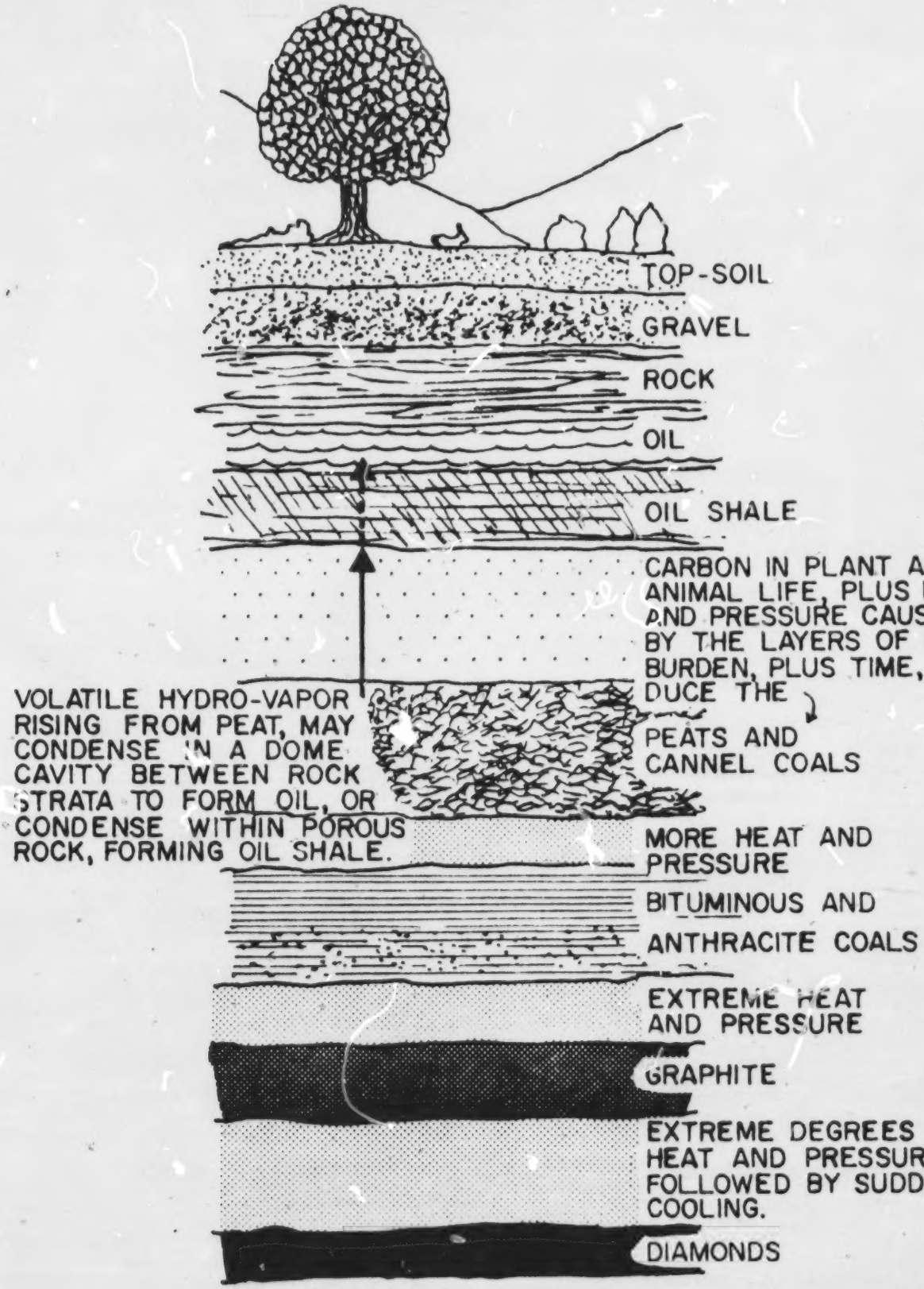
3. What evidence is there that the petroleum industry is making any changes in terms of a diminishing resource?

4. Has the increase in fuel and oil prices had any effect upon exploration activities?

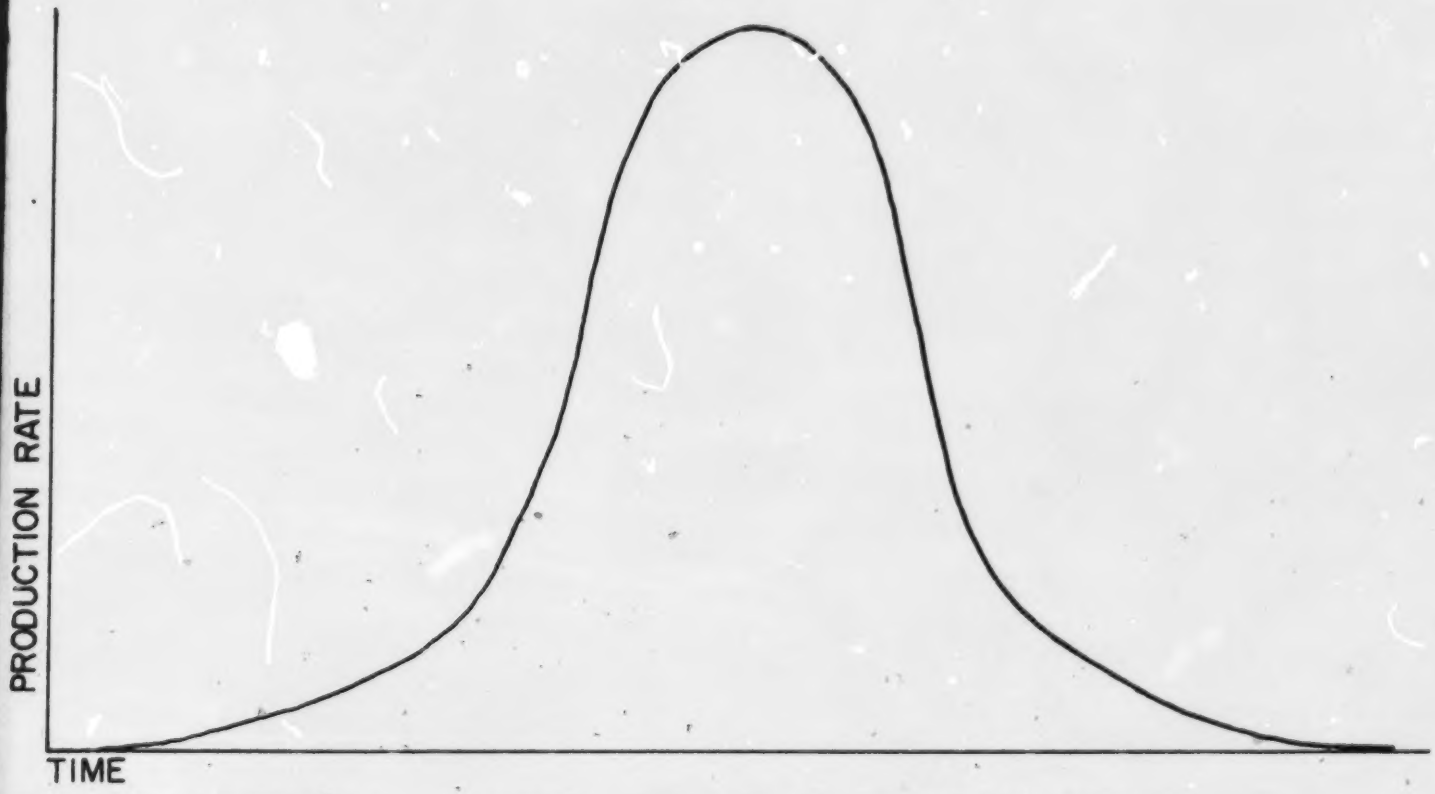
# PLAN OF FOSSIL FUELS IN MAN'S HISTORY



# CARBONS

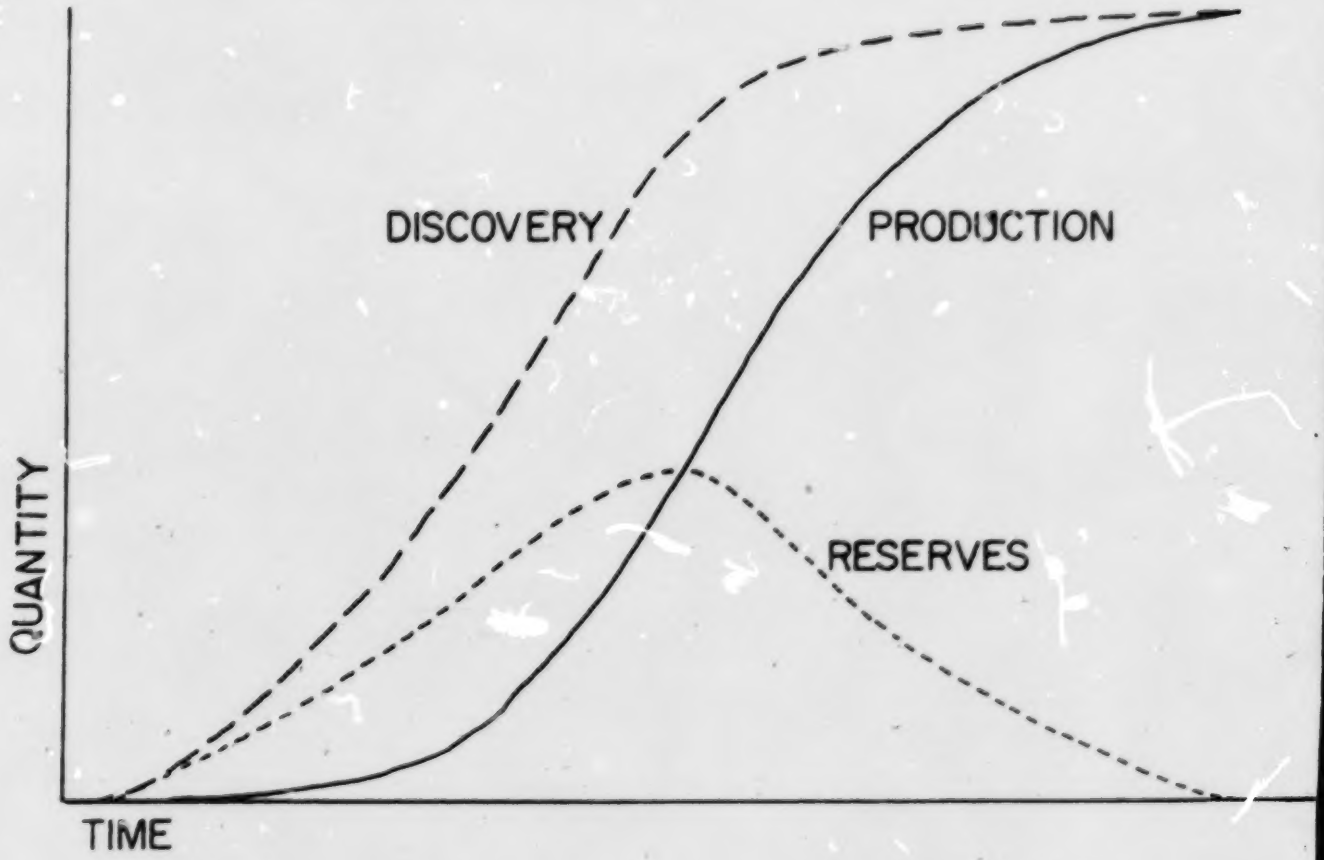

TOP-SOIL
GRAVEL
ROCK
OIL
OIL SHALE
CARBON IN PLANT AND ANIMAL LIFE, PLUS HEAT AND PRESSURE CAUSED BY THE LAYERS OF OVER-BURDEN, PLUS TIME, PRO-DUCE THE
PEATS AND CANNEL COALS
VOLATILE HYDRO-VAPOR RISING FROM PEAT, MAY CONDENSE IN A DOME CAVITY BETWEEN ROCK STRATA TO FORM OIL, OR CONDENSE WITHIN POROUS ROCK, FORMING OIL SHALE.
MORE HEAT AND PRESSURE
BITUMINOUS AND
ANTHRACITE COALS
EXTREME HEAT AND PRESSURE
GRAPHITE
EXTREME DEGREES OF HEAT AND PRESSURE, FOLLOWED BY SUDDEN COOLING.
DIAMONDS

# GROWTH CURVE OF EXHAUSTABLE RESOURCES

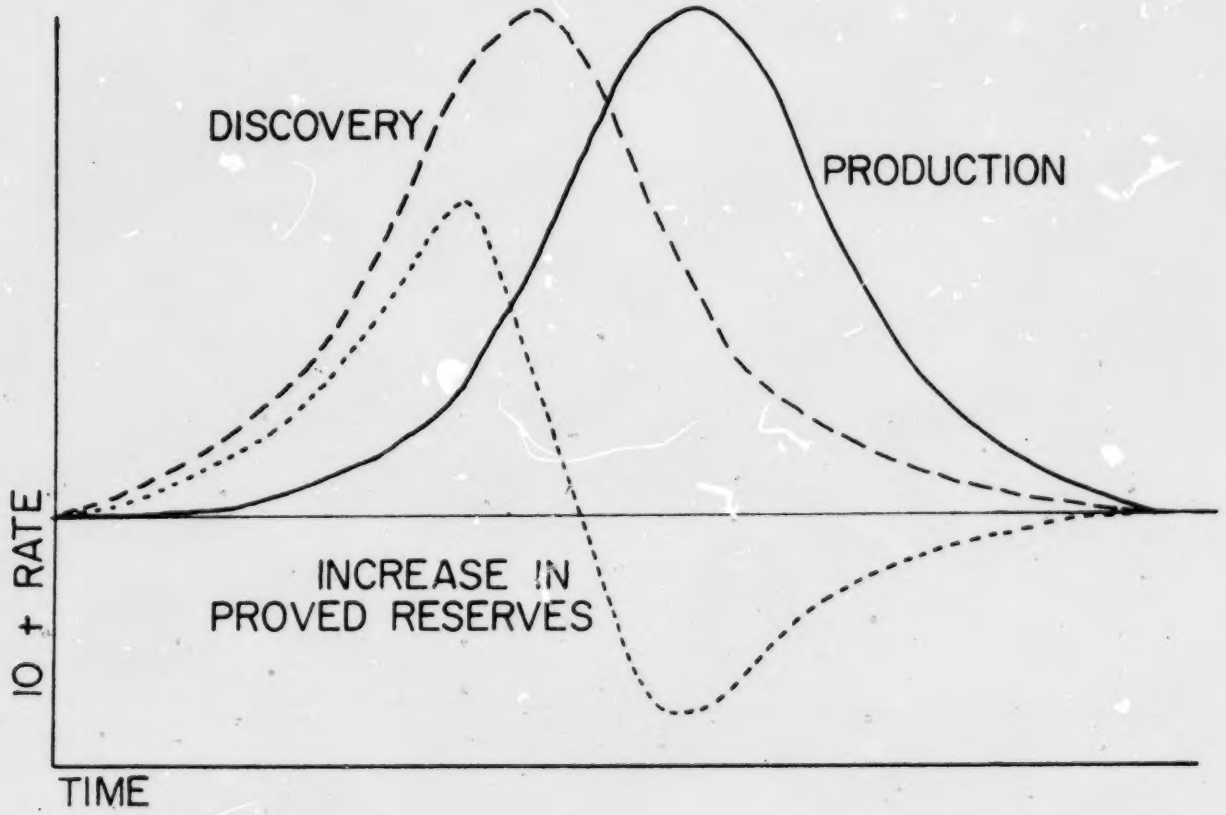



PRODUCTION RATE AS FUNCTION OF TIME

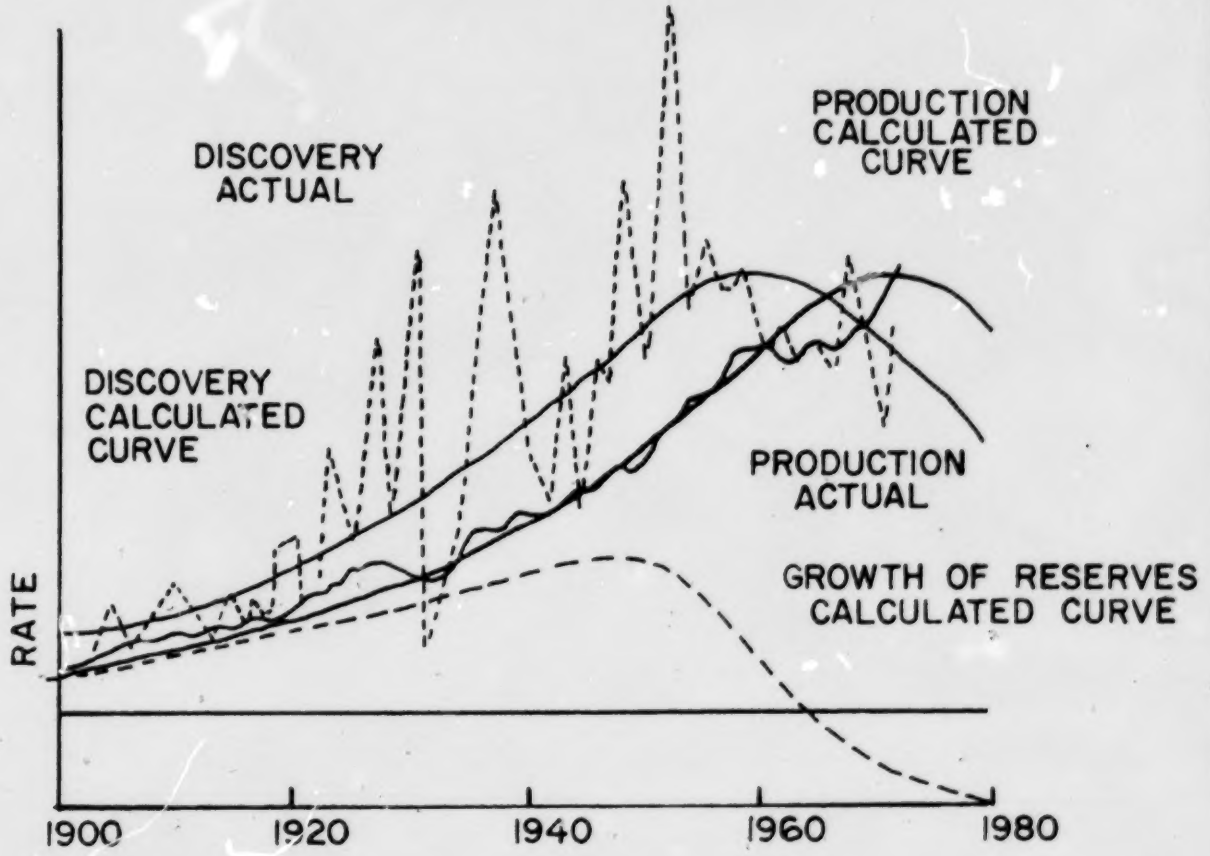
# CUMULATIVE QUANTITIES OF EXHAUSTABLE RESOURCES



# RELATIONSHIP BETWEEN RATES OF PRODUCTION, DISCOVERY, AND ADDITION TO RESERVES



# ACTUAL DISCOVERY AND PRODUCTION RATES OF EXHAUSTABLE RESOURCES



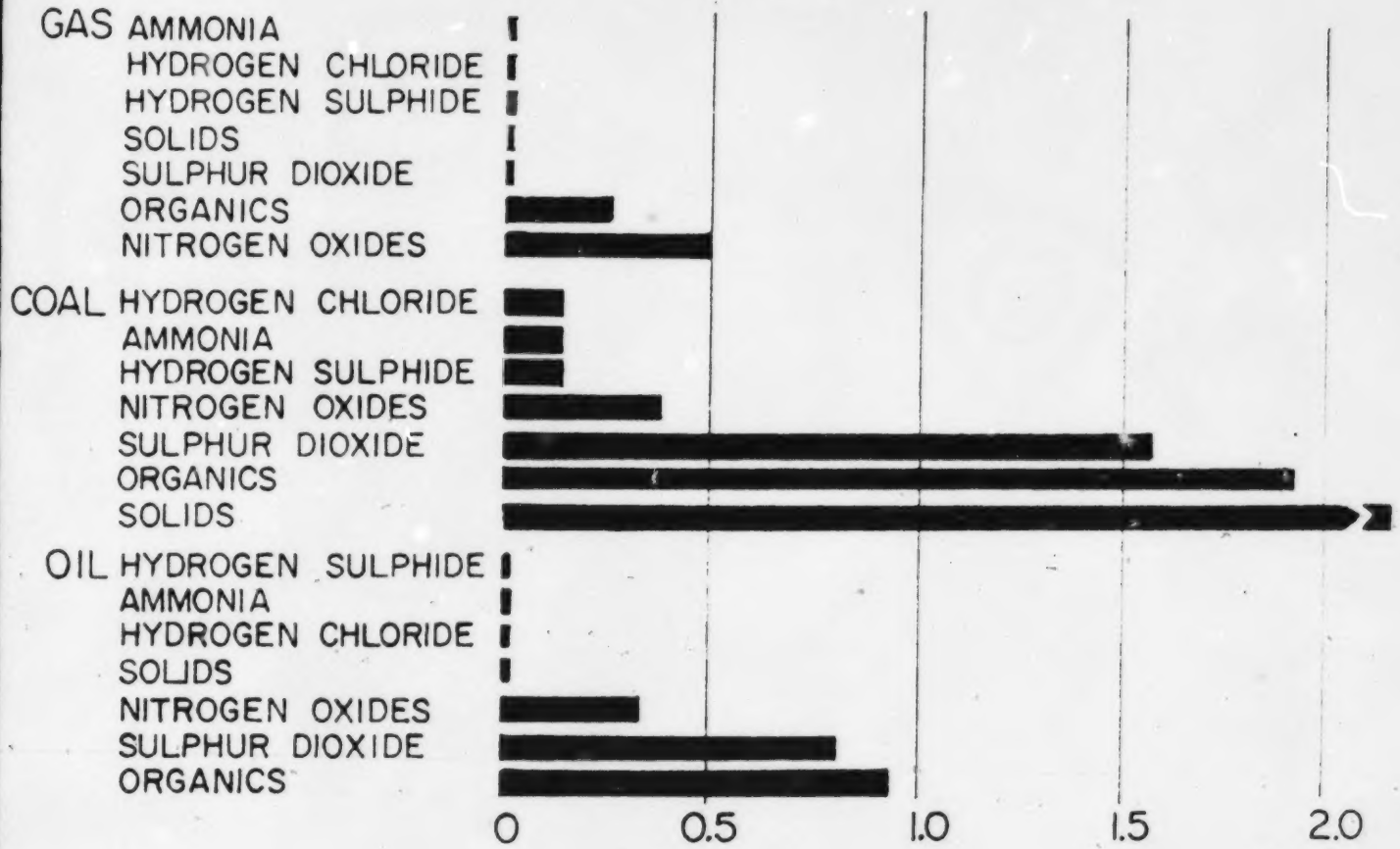
## SOURCES OF AIR POLLUTION IN THE UNITED STATES (1968)

| Sources | Carbon Monoxide $100 \times 10^6$ Tons | Sulfur Oxides $33 \times 10^6$ Tons | Hydrocarbons $33 \times 10^6$ Tons | Nitrogen Oxides $21 \times 10^6$ Tons | Particulates $28 \times 10^6$ Tons |
|---|---|---|---|---|---|
| Fuel burning for transportation | 63.8% | 2.4% | 51.9% | 39.3% | 4.3% |
| Fuel burning in power plants, home furnaces and other stationary sources | 1.9 | 73.5 | 2.2 | 48.5 | 31.4 |
| Industrial processes other than fuel burning, including petroleum refining | 9.6 | 22.0 | 14.4 | 1.0 | 26.5 |
| Solid waste disposal | 7.8 | 0.3 | 5.0 | 2.9 | 3.9 |
| Forest fires, coal waste fires, agricultural burning, gasoline marketing, etc. | 16.9 | 1.8 | 26.5 | 8.3 | 33.9 |

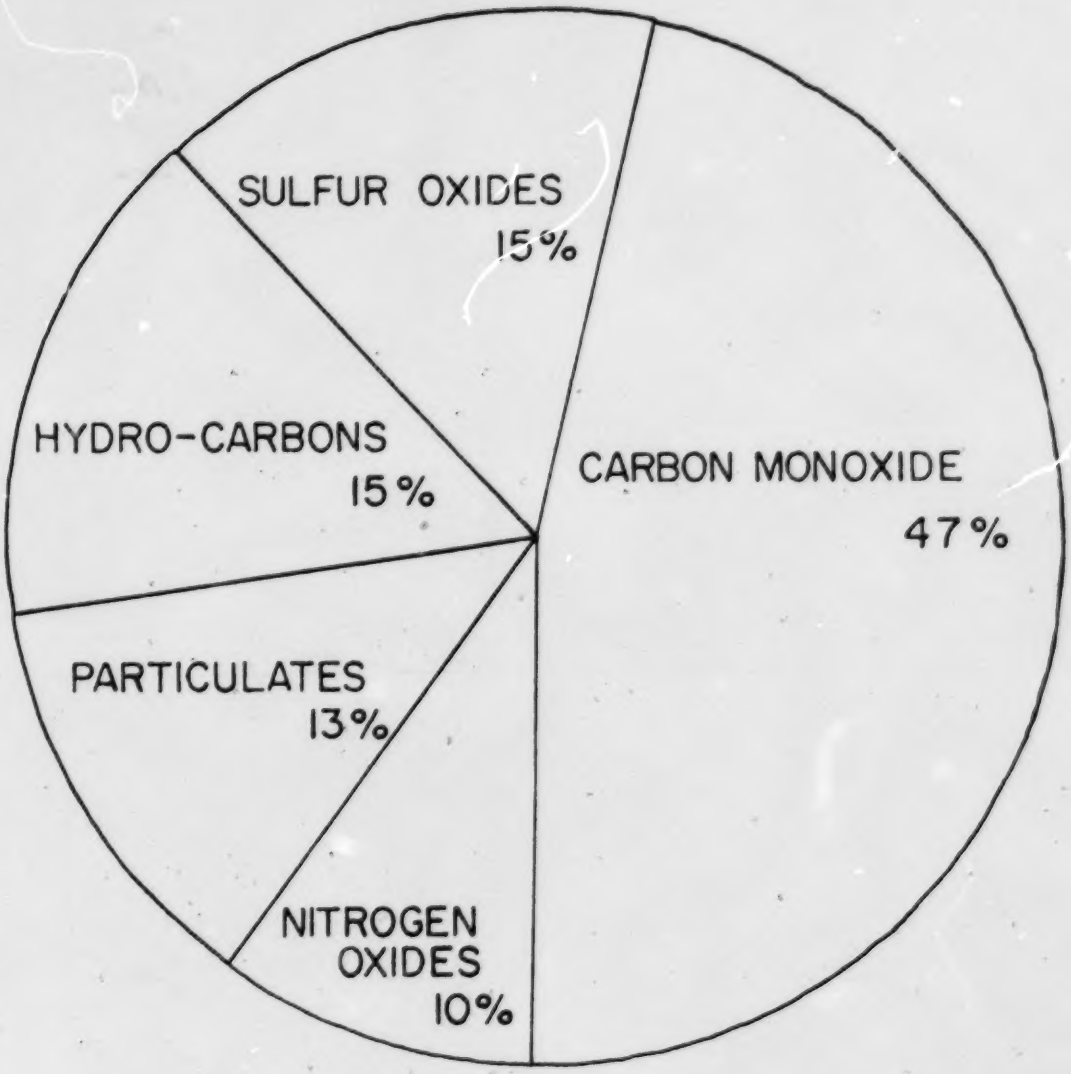
20

TM VII

# COMPARISON OF POLLUTANTS IN FOSSIL FUELS



# BREAKDOWN OF COMMON POLLUTANTS BY WEIGHTS



FOSSIL FUELS

UNIT TEST

I. Indicate correct response to the following statements by circling "T" for true statements and "F" for those statements which are false.

T F 1. Hydrocarbons make up major compounds of the petroleum family.

T F 2. Fossil fuels are formed as the result of the death and decomposition of living matter.

T F 3. Conversion of organic sediments to fossil fuels takes only a few hundred years to occur.

T F 4. Hydrocarbon compounds vary little in weight and composition.

T F 5. Methane is found as a gas under normal conditions of temperature and pressure.

T F 6. Natural seeps of petroleum have been known since ancient times.

T F 7. Petroleum products have been in widespread use for less than a hundred years.

T F 8. Basic techniques related to drilling for oil have changed very little from early days of the industry.

T F 9. A growing scarcity of whale oil and other lighting materials led to initial exploration for petroleum.

T F 10. The coming of the internal combustion engine had little influence on advances in petroleum usage.

T F 11. Petroleum resources being developed in Alaska will probably serve to delay peaking of production for the United States as a whole.

T F 12. World peak of petroleum production is likely to occur sometime around the middle of the next century.

T F 13. Cumulative amount of production of fossil fuels often exceeds cumulative amount of current usage.

T F 14. Estimates of total oil available plus rate of production show that about 80% of American production will be during the time period 1934-1999.

T F 15. Estimates suggest that past recovery of petroleum has been only about 1/4 of the total available of the oil within the well.

T F 16. Because of shortage, exploration success in terms of discovery per foot of exploratory drilling has increased greatly.

T F 17. Petroleum is generally processed through a refinery before using.

T F 18. Quantity of sulfur in oil has little effect on refining process used.

II. Match terminology with definitions below by placing letter of correct response in space provided beside definition.

_____ 19. Removing impurities of sulfur from crude petroleum

_____ 20. Process of distillation applied to petroleum

_____ 21. Use of shock artifically produced in geophysical prospecting

_____ 22. Oil well drilling in area not known to be productive

_____ 23. Hydrocarbon oil previously used for lighting now used as component of jet fuel

_____ 24. Gaseous hydrocarbon occuring naturally in decomposition of organic matter

_____ 25. High sulfur content crude oil

_____ 26. Organic compounds containing only carbon and hydrogen

_____ 27. Low sulfur content crude oil

A. "Wild-catting"

B. Methane

C. Sweet-crude

D. Refining

E. Sweetening process

F. Seismic

G. Sour-crude

H. Kerosene

I. Hydrocarbons

J. Gravitational effect

III. 28. The formation of fossil fuels is brought about by four factors in addition to the remains of living matter. What are these four factors?

A.

B.

C.

D.

29. Current explorations for petroleum have ranged into areas other than those previously considered. Name three areas now being explored.

A.

B.

C.

30. Original uses for petroleum were different than today's uses for fossil fuel. What are three early uses discussed in this unit?

A.

B.

C.

31. Demand for more petroleum products came about as a distinct result of several economic developments. Discuss three of those studied in this unit.

A.

B.

C.

FOSSIL FUELS

ANSWER SHEET

I. 1. T
2. T
3. F
4. F
5. T
6. T
7. T
8. T
9. T
10. F
11. T
12. F
13. F
14. T
15. T
16. F
17. T
18. F

II. 19. E
20. D
21. F
22. A
23. H
24. B
25. G
26. I
27. C

III. 28. Four factors affecting formation of fossil fuels:

A. Time

B. Microbial action

C. Heat

D. Pressure

29. Current exploration now being undertaken:

A. Desert areas

B. Ocean floor

C. Subpolar regions

30. Original uses for petroleum

A. Kerosene as illuminant

B. Lubricating oil

C. Oil for medicinal purposes

31. Factors influencing demand increase include:

A. Advent of electric lighting

B. Oil being used for firing boilers instead of coal

C. Scarcity of coal

D. Expense of coal

E. Shift of oil production west

F. Rise of automobile